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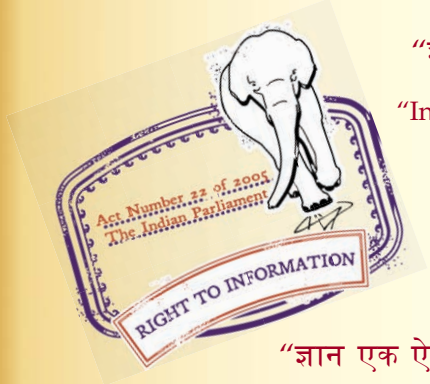

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Indian Standard

RECOMMENDED PRACTICE FOR SORTING OF FERROUS/NON-FERROUS MATERIALS USING ELECTROMAGNETIC (EDDY CURRENT) TECHNIQUE

ICS 77.040.20

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This document has been prepared as an aid for sorting of ferrous/non-ferrous materials using electromagnetic (eddy current) technique.

In the formulation of this standard assistance has been derived from:

i) ASTM E 566 - 82 : Standard Practice for Electromagnetic (Eddy Current) Sorting of Ferrous Metals

ii) ASTM E 703 - 79 : Standard Practice for Electromagnetic (Eddy Current) Sorting of Non-Ferrous Metals

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical value (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

RECOMMENDED PRACTICE FOR SORTING OF FERROUS/NON-FERROUS MATERIALS USING ELECTROMAGNETIC (EDDY CURRENT) TECHNIQUE

1 SCOPE

This standard covers the procedure for sorting ferrous as well as non-ferrous metals using the electromagnetic (eddy current) method. The procedure relates to instruments using absolute or comparator type coils for distinguishing variations in mass, shape, conductivity, permeability, and other variables such as chemical composition (alloy grade), heat treatment, hardness etc, that affect the electromagnetic response from the component to be tested. The selection of samples to determine sorting feasibility and to establish calibration standards is also included.

2 REFERENCE

The following standard is a necessary adjunct to this standard:

IS No.	*Title*
12965 : 1990	Glossary of terms used in electromagnetic (eddy current) testing

3 DEFINITIONS

The definitions listed in IS 12965 shall apply in connection with the procedure outlined in this practice.

4 SUMMARY OF PRACTICE

4.1 The two techniques that are primarily used in electromagnetic sorting employ the absolute (single) and comparative (two) coil methods. The decision of whether to use single-coil or two-coil operation is usually determined by empirical data. In the absolute coil method, the equipment is calibrated by placing standards of known properties in the test coil. The value of the conductivity in test parameter (for instance, hardness, alloy grade, or heat treatment) is read on the scale of an indicator. In the comparative coil method, the test piece is compared with a reference piece and the indication tells whether the piece is within or outside of the required limits.

4.1.1 *Absolute Coil Method*

A sample of known classification is inserted in the test coil and the controls of the instrument are adjusted to obtain an indication. The test is then continued by inserting the pieces to be sorted into the test coil, and observing the instrument indication.

4.1.2 *Comparative Coil Method*

Known reference pieces representing the minimum or maximum limits of acceptance, or both, are inserted in the reference coil and test coil. The instrument controls are adjusted for appropriate indications. The test is then continued by inserting the pieces to be sorted in the test coil, keeping reference specimen in the reference coil, and observing the change in instrument indication.

4.2 The range of instrument indication must be adjusted during the calibration such that the anticipated deviations shall lie within the range of read out depending on whether a two-way or three-way sorts are to be accomplished.

4.3 Both absolute and comparative methods require comparing the pieces to be tested with the reference piece(s). Two or more samples representing the limits of acceptance may be required. In the absolute method the electrical reference is generated by a test piece. In the comparative method any electromagnetic condition that is not common to the test specimen and the standard will produce an imbalance in the system. The comparative method is usually more stable, as it normally suppresses all internal and external disturbance.

4.4 The testing process may consist of manual insertion of one piece after another into the test coil, or an automated feeding and classifying mechanism may be employed. In automated set up, it is sometimes necessary to stop each piece momentarily in the test coil while the reading is being taken, especially if low test frequencies are employed.

5 SIGNIFICANCE

5.1 Absolute and comparative methods provide a comparative measure for sorting large quantities of ferrous parts of stock with regard to composition; condition; and structure or processing or both.

5.2 The comparative or two-coil method is used when high-sensitivity testing is required. The advantage of this method is that it almost completely suppresses all internal or external disturbance such as temperature

variations or stray magnetic fields. The two-coil method is also useful when harmonic evaluation is employed for sorting.

5.3 The ability to accomplish satisfactorily these types of separations is dependent upon the relation of the electromagnetic characteristics of the electrically conducting parts to their physical condition.

5.4 These methods may be used for high speed sorting in a fully automated set-up where the speed of testing may approach ten pieces per second depending on their size and shape.

5.5 The success of sorting ferromagnetic material depends mainly on the proper selection of magnetic field strength (coil current) and frequency of exciting current in the test coil, fill factor, and variables present in the sample.

5.6 The degree of accuracy of a sort will be affected greatly by the coupling between the test coil field and the tested part and the accuracy with which the tested part is held in the test coil field during the measuring period.

5.7 When high currents are used in the test coil, a means should be provided to maintain a constant temperature of the test standard in order to minimize drift of the test results.

6 INTERFERENCES

6.1 The specific influence of the following variables shall be considered for proper interpretation of the results obtained.

6.1.1 The correlation shall be established so that electromagnetic properties of various groups do not overlap and are well defined in the calibration procedure used.

6.1.2 In sorting magnetic materials, a magnetic field strength (coil current) and test frequency shall be used that will result in a well-defined separation of variables being tested.

6.1.3 When examining magnetic materials at low field strength (coil current), any influence from the previous magnetic history of the part on the test (residual magnetism) shall be negated by demagnetization of the part if it restricts the electromagnetic sorting.

6.1.4 The temperature of the standard and test part shall be controlled within limits that will permit a well-defined range of conductivity or permeability, or both, for which the correlation of the group or groups is valid, cooling of the test standard when high field strength (coil currents) are used or allowing test parts to cool or heat to an established ambient range, or both, may be required.

6.1.5 The geometry and mass of the standard and test part shall be controlled within limits that will permit sorting.

6.1.6 *Speed Effects — See* **4.4**.

7 APPARATUS

7.1 Electronic Apparatus

The electronic apparatus shall be capable of energizing the test coil with alternating currents of suitable frequencies and power levels and shall be capable of sensing the changes in the electromagnetic response of the coils. Equipment may include any suitable signal-processing devices (phase discriminator, filter circuits etc) and output may be displayed by meter, scope, recorder, signalling devices or any suitable combination required for the particular application. Typically 1 Hz to 100 Hz frequency system may be used.

7.2 Test coils may be of encircling or probe-coil type and shall be capable of inducing electromagnetic field in the test specimen and standard and sensing changes in the electric and magnetic characteristics of the test specimen.

7.2.1 When selecting the test coil, the objective should be to obtain a coil fill factor as large as possible. This means that the enclosed area of the test coil should be filled by the test piece as much as possible. This is of primary importance for tests requiring high sensitivity.

7.2.2 For complicated test piece shapes, a corresponding insert shall be provided to ensure that each test piece can be placed in the same position within the test coil. These inserts, as well as any other accessories, should be made of electrically nonconductive and nonferromagnetic material.

7.3 Mechanical Handling Apparatus

A mechanical device for feeding and sorting the test specimens may be used to automate the particular application.

8 TEST SPECIMEN OR SAMPLE (CALIBRATION STANDARDS)

8.1 A known acceptable sample and known unacceptable sample of the precise size and configuration of the product to be tested shall be used to set up for sorting by the absolute coil (*see* **9.2**) or comparative coil (*see* **9.3**) method.

8.2 Three known samples are required for a three-way mix (*see* **9.4**).

8.3 The sample should be selected to represent the

extremes of acceptable and unacceptable groups and to assure no overlap in the sorting.

8.4 The pertinence of the samples, thus prepared, should be checked for every batch. The batches may be kept separate as per heat treatment, alloy grade, or some such relevant parameter. It may be necessary to prepare reference samples afresh for every batch so that influence of interfering parameters is kept to a minimum.

9 CALIBRATION AND STANDARDIZATION

9.1 The electromagnetic sorting method is primarily one of comparison between pieces. Empirical data and physical tests determine classification. The calibration and standardization procedure shall be governed by the properties of the sample requiring separation.

9.2 When using the absolute coil method, insert the calibration standard to a fixed position in or relative to the coil and adjust the test instrument to get a reading in the meter or the scope or both. Replace the acceptable standard with a known unacceptable standard in the same exact position and adjust the sensitivity of the instrument to maximize the difference in the indicator reading without exceeding 90 percent of the available scale range.This may require repeated checks and readjustment in the sensitivity with acceptable and unacceptable standards.

9.3 When using the comparative coil method, select a reference piece (usually one that falls within the acceptable limits of the pieces being tested) and place it in the reference coil in such a way that it will not be disturbed, and set this coil and reference piece out of the way. For this method, when confronted with a two-way mix, choose two calibrated standards, one of which represents the acceptable and the other the unacceptable group. Place the acceptable calibration standard to a fixed position in the test coil coinciding with the position of the reference piece in the reference coil and balance the instrument. Replace this acceptable calibration standard with one representing the unacceptable group and adjust the test instrument's phase, sensitivity and coil current, then amplify to maximize the indicator reading without exceeding ± 90 percent of the available scale range. Reinsert the acceptable standard and alternately readjust the instrument controls to attain a balanced value for the acceptable standard and a maximum indication for the unacceptable standard.

9.4 For a three-way sort, it is best to have three calibration standards, two of which represent the high and low limits of acceptability for one group or one each of the two unacceptable groups. The third standard, of course, represents the acceptable lot of material.

9.4.1 A typical case for the former usually consists of hardness or case depth measurements where standard representing maximum and minimum limits are required. In this instance, insert the third standard representing the acceptable lot into the test coil and adjust the instrument for a balance or zero reading. Then adjust the controls to maximize the indications without exceeding ± 90 percent of the available scale range from the balance for each of the other two standards (maximum and minimum). Alternate readjustment of the controls may be necessary to retain the balance reading, as well as the maximum and minimum limits for acceptance.

9.4.2 For a three-way sort when three dissimilar grades of material become mixed, place the third standard (acceptable group) into the test coil and balance. Then successively insert into the test coil the two standards representing the other two grades and adjust the instrument's controls to maximize the indications without exceeding ±90 percent of the available scale range from the balance for each of the other two standards. Alternate readjustment of the controls may be necessary to retain the balance reading as well as the indication for the other two standards.

9.5 When high current is used in the comparative test method, the reference piece is likely to heat up and this will change its electromagnetic response. It is necessary to provide for cooling or to have several identical reference pieces so that they can be interchanged to prevent drift in the balance. Another method that may be used is to momentarily turn off power to the coils when pieces are not being tested.

10 PROCEDURE

10.1 Connect the required test coil to the instrument, place insert(s) or other positioning fixture in the coil(s), if required.

10.2 Switch on the instrument and allow it to warm up for at least the length of time recommended by the manufacturer.

10.3 Make all necessary set up and control adjustments in accordance with the manufacturer's recommendation. Adjust frequency, field strength (coil current) sensitivity and other necessary controls to values determined for the electromagnetic sort.

10.4 Calibrate the sorting system in accordance with **9.2** when using the absolute coil method or **9.3** when using the comparative coil method. Calibrate at the start of the test run and at least once every hour of continuous operation or whenever improper

functioning of the system is suspected.

10.5 For manual operation, insert the test pieces manually in the test coil.

10.5.1 Read the test results on an indicator.

10.5.2 Manually remove the pieces from the test coil.

10.6 For automatic sorting, pass the test pieces continuously through the test coil in identical fashion.

10.6.1 Each test piece in passing through the coil is analyzed by the test instrument.

10.6.2 A signal, corresponding to the quality of the respective test piece, is sent to a sorting gate where the tested pieces are automatically sorted into preselected quality groups.

10.7 Verify the calibration of the instrument at end of testing each lot. If the calibration is found to have changed since the last check so that it effects the sorting. Repeat the test after recalibration of all the material tested since last check.

11 INTERPRETATION OF RESULTS

11.1 The results of any non-destructive testing procedure are based on the comparison of an unknown with a standard. Unless all of the significant interrelationships of material or product properties are understood and measurable for both standard and unknown samples, the test results may be meaningless.

11.2 Electromagnetic sorting is best used for respective tests on material 'identical' in shape, composition, and metallurgical structure, and not for tests on grossly different materials. Electromagnetic sorting is generally not useful if there is limited knowledge of the properties of the unknown or test material.

11.3 Interpretation of data depends upon the degree to which the test materials compare with the reference materials. It is necessary to have all variables, except the one selected as a basis for sorting, under sufficient controls if the measured variation is to be properly interpreted. Results can often be interpreted or explained by a change in process parameter, such as in temperature, composition, and inclusions, when the measured property is known to be a function of the processing procedure.

11.4 Often, only a general interpretation of sorting results can be made. The parts can be said to be different but the how and the why of the difference usually is not determinable.

11.5 When the spread in value of the measured variable is sufficient, electromagnetic sorting can be 100 percent effective. However, there may be cases where a single test will not show a clear separation. Often a second test or procedure can be used to further define the separation of materials. For example, a change in test frequency may show the effect of a second variable.

11.6 Shape and surface variations can mask the test results. If surface hardness is desired as the basis for sorting, all material should have composition and surface roughness under sufficient control so that effects of variations in hardness can be separated.

12 REPORT

The written report of an electromagnetic sorting should contain any information about the test set up that will be necessary to duplicate the test at the same or some other location, plus such other items as may be agreed upon by the producer and purchaser. The following information should be recorded:

i) Description of apparatus :
   Type of equipment :
   Model No. :
   Serial No. :

ii) Recorder (if used) :
   Type :
   Model No. :
   Serial No. :

iii) Coil :
   Size :
   Type :

iv) Other interconnecting apparatus :

v) Reference Standards :

vi) Test frequency :

vii) Description of materials :
   Geometry :
   Chemistry :
   Heat treatment :

viii) Method of calibration :

ix) Field strength (coil current) :

x) Speed of testing :

xi) Temperature of the standard :

xii) Temperature of the test sample :

xiii) Whether sample was demagnetized or not :

xiv) Test Method :

13 PRECISION AND ACCURACY

Measurement accuracy depends upon factors including the equipment, techniques, control of temperature of parts and standard, geometry, magnetic history of the part, field strength (coil current) used, types of materials, accuracy of the sorting. Results in the majority of sortings can be expected to be quite accurate, with a single combination of the above factors and selection of a point on the magnetization curves (field strength, coil current) at which each curve is displaced from its nearest neighbour by substantial distance (probably within a 1 percent tolerance). The field strength is usually determined empirically and the care with which it is determined will effect the precision and accuracy.

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